Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 111 (2015) 398 – 403

Procedia Engineering

www.elsevier.com/locate/procedia

XXIV R-S-P seminar, Theoretical Foundation of Civil Engineering (24RSP) (TFoCE 2015)

Deformability and strength determining of coupling fittings of steel reinforcement in the reinforced concrete structures

Sergey N. Karpenko[a], Vladimir I. Travush[a,b,c], Igor G. Chepyzubov[a]*

[a] *Research Institute for Building Physics of Russian Academy of the Architecture and Construction Sciences; 21, Locomotivniy Proezd, Moscow, 127238, Russia*

[b] *Russia Urban planning institute of residential and public buildings (GORPROJECT); 15, Bldg. 15, Academika Tupoleva Emb., Moscow, 105005, Russia*

[c] *Russian Academy of Architecture and Construction Sciences; 24-1, Ulitsa Bolshaya Dmitrovka, Moscow, 107031, Russia*

Abstract

The fittings on the thread which replace the traditional lap connection begin to find more and more application in reinforcing of modern reinforced concrete structure. The valuation techniques of deformability and strength of coupling fittings of reinforcement

on the thread which are increasingly used in construction is presented. The method is based on the comparison of stress-strain diagram of one-piece reinforcing bar with the stress-strain diagram of the connecting rod in the place of installation fitting. On the basis of experimental studies of stress-strain diagrams of one-piece reinforcing bar and butt joints of its rods it was found that the joints of reinforcing bar are more deformation. By comparing of the strain of butt joint with the same of one-piece reinforcing bar corresponding to the calculated deformations of the reinforcement ε_s and $\varepsilon_{s\,0.2}$ there are determined the coefficients of the reduction factors of these deformations γ_s in the butt joints which used at designing of reinforced concrete structures.

Peer-review under responsibility of organizing committee of the XXIV R-S-P seminar, Theoretical Foundation of Civil Engineering (24RSP)

Keywords: Reinforcement, Fittings, Strain, Stress-strain diagrams, Strength, Deformation

* Corresponding author. Tel.: +7-495-482-4018.
E-mail address: niisf_lab9@mail.ru

Peer-review under responsibility of organizing committee of the XXIV R-S-P seminar, Theoretical Foundation of Civil Engineering (24RSP)
doi:10.1016/j.proeng.2015.07.107

Nomenclature

σ_s – reinforcement stress,
ε_s – relative deformations,
d_s – reinforcement bar diameter,
$l_м$ – sleeve coupling length,
l – estimated sleeve coupling length,
R_{sc} – design sleeve coupling compressive strength,
$\sigma_{sc}, \sigma^*_{sc}$ – reinforcement stress I, conforming to estimated relative deformations $\varepsilon_s = 2 \cdot 10^{-3}$, $\varepsilon_s = 2.5 \cdot 10^{-3}$,
$R_{scм}$ – estimated sleeve coupling compressive stress,
$\sigma_{0,2}$ – estimated sleeve coupling tensile stress,
$\sigma^*_{scm}, \sigma_{scm}$ – junction stress conforming to estimated relative deformations $\varepsilon_s = 2 \cdot 10^{-3}$, $\varepsilon_s = 2.5 \cdot 10^{-3}$,
$\sigma_{0,2m}, \widetilde{\sigma}_{0.2m}$ – estimated sleeve coupling tensile stress, conforming to relevant permanent residual reinforcement deformation in distressed condition $\varepsilon_s = 2 \cdot 10^{-3}$,
σ_{el} – reinforcement stress, conforming to elastic deformation stage,
E_s – reinforcement bar elasticity modulus,
γ_E, $\gamma_{cм}$, $\gamma^*_{cм}$, $\gamma_м$ – decreasing coefficient for sleeve coupling estimated values: elasticity modulus (γ_E), compression strength ($\gamma_{cм}, \gamma^*_{cм}$), tensile strength ($\gamma_м$) respectively.

1. Introduction

Construction sites in Russia are increasingly using sleeving of bars with the help of threaded couplings instead of previously used lapping of bars. Currently various foreign firms («Erico», «Dextra», «Hebei Yada reinforcing Bar Connecting Technology Co.» and others) are listed among the suppliers of such couplings. In conformance with Russian standards [1] load bearing capacity of the sleeved system should not be less than load bearing capacity of unconnected reinforcing rod. The feasibility of this requirement can be determined with the diagram technique elaborated by the Research Institute of Structural Physics at Russian Academy of Architecture and construction sciences [2] for determining strength of a sleeved system. This paper gives further development to this technique.

The above technique indicates that the strength of a sleeved system is lower than that of a one-piece rod. It also allows to determine the coefficients of working conditions, reduces strength and increasing deformability of coupling joint. The values of these coefficients must be taken into consideration during the design process.

2. Diagram technique to determine strength and deformations of sleeved system.

The methodology laid comparison chart linking stress with relative deformation of the reinforcing bar (charts « $\sigma_s - \varepsilon_s$ » without coupling), a similar diagram of two rods to be joined with a coupling. Length (base), on which union coupling joint deformities are metered $l = l_м + 2d_s$, where l_m – coupling length d_s – diameter of reinforcement bars to be joined; strains in the rods to be joined (as in the case of one-piece bars) are accepted as strains σ_s.

At the beginning of the test, a chart is obtained experimentally showing the deformation of the original reinforcement. Schematically, this diagram is shown in Fig. 1 as a line I. In the line four points are marked as 1, 2, 3, 4, where point I corresponds to the end of the linear section of the diagram (stress σ_{el}), points 2,3 – maximum compressive stress in the reinforcement $\sigma_{sc} = R_{sc}$, which allow standards to be used while the reinforcement operates under compression (for short-term and long-term stress respectively), point 4 - maximum permissible values $\sigma_s = \sigma_{0,2}$ under tension. The position of point 2 is determined by the maximum compressive strain of concrete at the top of the deformation diagram of concrete in compression, which is equal to $2 \cdot 10^{-3}$.

Since the deformation of the reinforcement bar in concrete in compression is $\varepsilon_b = \varepsilon_s$, then at the moment of concrete deterioration the reinforcement deformation will be also equal to $\varepsilon_s = 2 \cdot 10^{-3}$. Thus, the value σ_{sc} (at elasticity modulus of the reinforcement bar E_s =2,0 $\cdot 10^5$ MPa) shall not exceed the value of 400 MPa, which corresponds to the above concrete shrinkage.

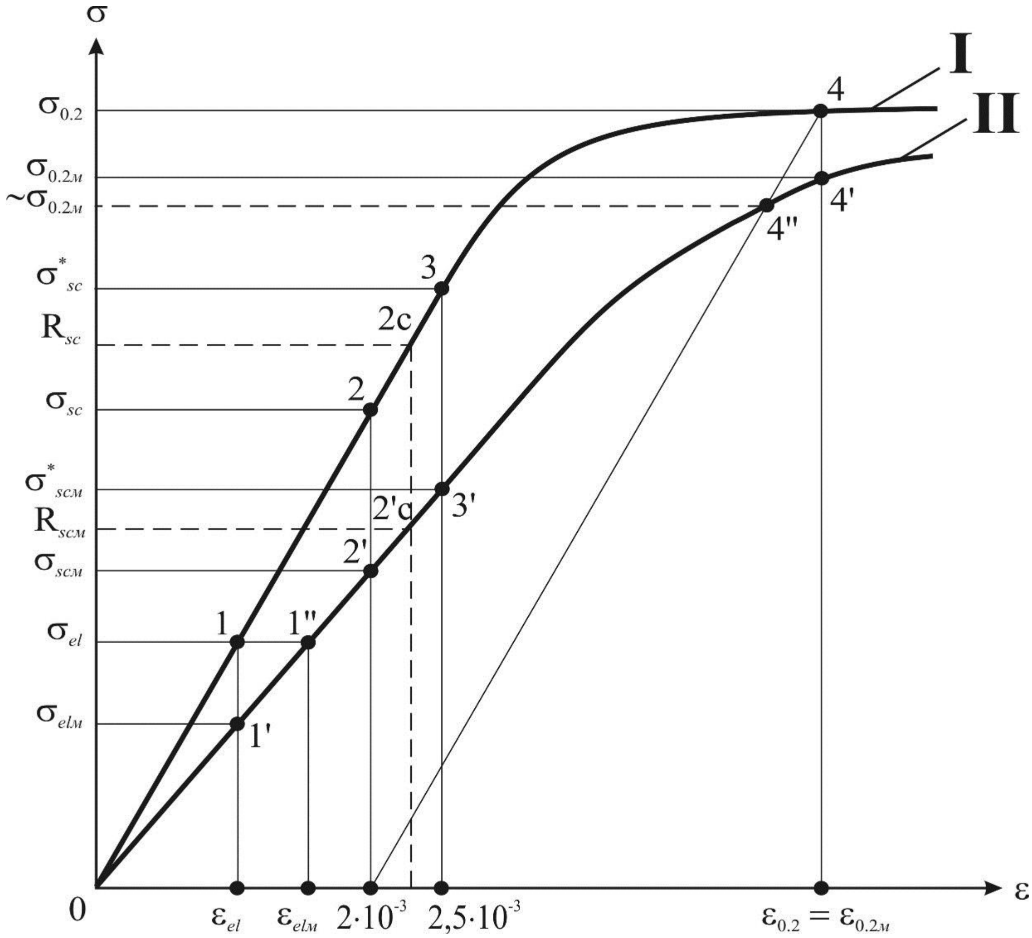

Fig. 1. Comparison of a diagram showing deformation of one-piece reinforcement bar (I) with a diagram of sleeve system deformation (II).

When calculating the structures in view of durable part of the load, the standards allow taking the design resistance of the reinforcement bar with values not exceeding $\sigma_{sc} = R_{sc} = 500$ MPa. This value corresponds to concrete deformation $\varepsilon_b = \varepsilon_s \approx 2{,}5 \cdot 10^{-3}$ instead of $\varepsilon_b = \varepsilon_s = 2 \cdot 10^{-3}$.

Under tension of elements, reinforcement stress should not exceed physical (or conditional) yield point of reinforcement $\sigma_{0,2}$. This stress corresponds to point 4 on diagram I (Fig. 1). Point 4 must comply with the residual strain in the reinforcement during in de-stressed condition, which is equal to $2 \cdot 10^{-3}$, therefore, there is a pure coincidence in standard permanent strain of the reinforcement bar and concrete deformations $\varepsilon_b = 2 \cdot 10^{-3}$ at the top of compression diagram. Deformation diagram for sleeved system II in (Fig. 1) is located below diagram I. It was established on the basis of coupling testing. Therefore, all of the above characteristics for sleeved system are lower than for one-piece bar without coupling (points (1"), 2', 3' и 4' (4")).

Decreasing coefficients result from comparison of diagrams I and II. The following relationships have been found: elasticity moduli for points.

1 and 1' (relationship is equal to γ_E), compression stress σ_{sc} for points 2' and 2 ($\gamma_{см}$ - relationship σ_{sc}) and points 3' and 3 ($\gamma^*_{см}$), tensile strength $\sigma_{s0,2}$ ($\gamma_м$) for points 4 and 4' (4'' is possible).

For instance, permissible concrete deformations in compression $\varepsilon_b = \varepsilon_s = 2 \cdot 10^{-3}$ will correspond to point 2' on diagram II and, therefore, a lower stress value $\sigma_{scм}$ in a reinforcement junction with respect to stress σ_{sc} in a one-piece reinforcement bar. Coefficient of reduction will be equal to $\gamma_{см} = \sigma_{scc} / \sigma_{sc}$. Allowable design compression resistance of reinforcement bar in the joint will be $R_{scм} = R_{sc} \cdot \gamma_{см}$.

When necessary, coefficients $\gamma_{см}$, $\gamma^*_{см}$ are clarified by further testing of couplings in compression and making diagrams similar to I and II. Similar tests has shown that diagrams I and II obtained under tension can be previously used. Reducing the deformation module per $\gamma_м$ coefficient is to be taken into consideration while crack width determination.

The above technique relates to quality control in conditions of a construction site. The coefficient values γ_E, $\gamma_{см}$, $\gamma^*_{см}$, $\gamma_м$ found should not be less than values indicated in the passport and product certificate. Meanwhile, estimated deviation of above characteristics with the accounts of precision in sleeved system should be taken into account in-situ (values γ_E, $\gamma_{см}$, $\gamma^*_{см}$, $\gamma_м$ are to be determined with the proximity of 0,95). The above values are accepted as standard. All standard values of coefficients γ_E, $\gamma_{СМ}$, $\gamma^*_{СМ}$, $\gamma_М$ have to be stated by the manufacturer in the passport, and research and design support at a construction site should be focused on their control.

For the time being, current sleeve systems passports do not contain the above characteristics. This state of things assumes that individual couplings can be stated as allowable providing decreasing coefficient only: γ_E, $\gamma_{см}$, $\gamma^*_{см}$, $\gamma_м$ to design reinforcement bar characteristics, obtained by testing based on the above technique.

3. Sleeve systems test results

Laboratory for «Quality and durability problems in construction» at the research Institute of Construction Physics at Russian Academy of Russian Academy of Architecture and construction sciences has made tests of lots of sleeved systems from various producers. Here are some teat results. All joints were made for A500 class reinforcement bars ($R_{sc} = 400 - 435$ MPa).

Fig. 2a,b represents diagrams of «Lenton» sleeved systems with tapered screw thread. Tests results have shown that the quality of the joints mainly depends on thread quality mainly depend on of thread cutting quality in coupling sleeve.

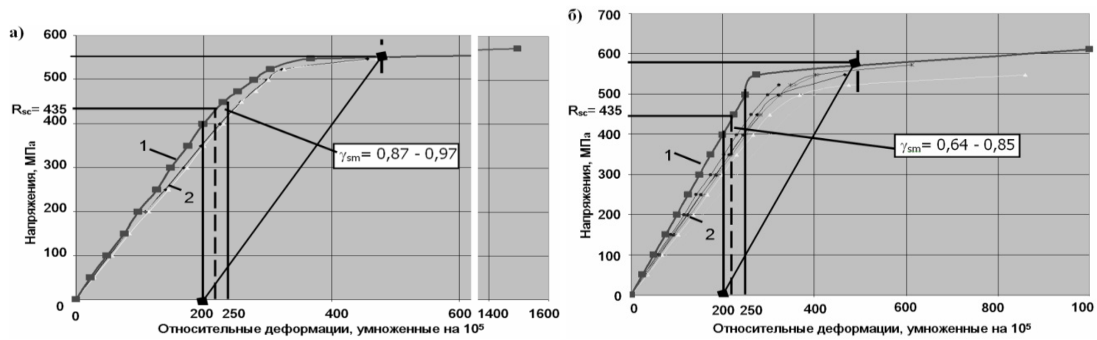

Fig. 2. Deformation diagrams of «Erico» sleeved systems: a) Chasing threads made by «Erico»; b) Chasing threads made by a «Ant-Yapy» representative in conditions of construction site); 1 – deformation diagram of one-piece reinforcement bar, 2 – diagrams in coupling joint sections.

Thus in the thread cutting process, being made by a qualified «Erico»expert, the deformation sleeve system diagram $(\sigma_s - \varepsilon_s)$ for was approximate to a similar reinforcement bar diagram (Fig. 2a). Decreasing coefficient of design compression resistance $\gamma_{sm} \approx 0{,}87 - 0{,}97$, in tension $\gamma_{sm} \approx 1$.

Fig. 2b represents sleeve system deformation diagrams, made by construction workers in conditions of a construction site. For the above joints $\gamma_{sm} = 0{,}70 - 0{,}85, \gamma_m = 0{,}94 - 0{,}99$.

Provided proper building quality control in condition of a construction site $\gamma_{sm} \approx 0{,}78 - 0{,}81$.

Tests schedule of «Dextra» sleeve coupler systems are represented in Fig.3a, b.

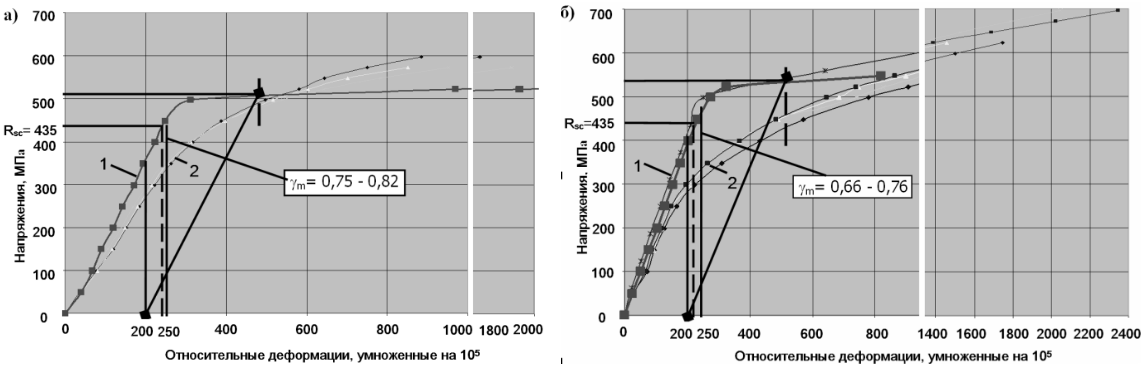

Fig.3 Deformation diagrams «Dextra» sleeve couple systems: a) Thread chasing and coupling made by a company representative; b) In-situ thread chasing and coupling.

The same trend is also observed during tests as for «Erico» joints. «Dextra» joints (Fig. 3a, $\gamma_{sm} \approx 0{,}75 - 0{,}82$,) have shown better results rather than ones made in-situ (Fig. 3,b, $\gamma_{sm} \approx 0{,}66 - 0{,}76$).

Russian construction sites have recently been using sleeve couplings supplied by Chinese manufacturers, e.g. «Hebei Yada». Thses couplings, including the above mainly depends on in-situ manufacturing quality and require strict control. Meanwhile, sleeve coupling quality can significantly vary $\gamma_{sm} \approx 0{,}873 - 0{,}65$.

«Erico» sleeve couplings were destroyed, mainly due to reinforcement rod pull-out of the coupling (Fig. 4a), «Dextra» sleeve couplings destructions resulted from reinforcement bar breakdown at the edge of the reinforcement bar junction with sleeve coupling (Fig. 4b), «Hebei Yada» sleeve coupling were destroyed due to reinforcement bar breakdown beyond the junction point.

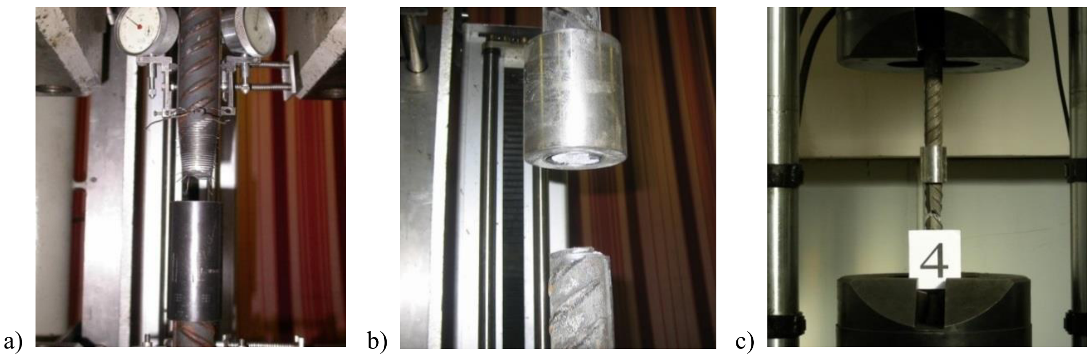

Fig. 4 Destruction of sleeve coupling test samples: a) produced by «Erico»; b) produced by «Dextra»; c) produced by «Hebei Yada».

4. Basic assumptions

1. Threaded sleeve coupling strength characteristics mainly depend on in-situ threading quality.
2. The above discrepancy in threaded sleeve coupling characteristics should be taken into account by introducing working conditions coefficients for sleeve coupling operation: γ_{sm} - for compressed column shaped reinforced concrete items and γ_m - for bended plate-type elements within a tension area.
3. Working conditions coefficients are to be determined experimentally at couplings certification stage and specified in certificates as well as controlled in-situ in compliance with the diagram technique proposed.
4. Taking into account lower resistance of sleeve couplings, the number of bars to be joined per one thread with the help of sleeve couplings should not exceed 50%. The distance between closely located edges of sleeve couplings should be no less than 0,5 lan , where lan- rods anchorage length, and no less than $4l_m$ where l_m - sleeve coupling length.
5. Supplementary structural lateral reinforcement is to be installed in places of sleeve coupling joints.
6. Reducing sleeve coupling deformation module is to be taken into account while determining the deformation of cracked reinforced concrete elements and while crack width estimation.

References

[1] Code Specification СП 63.13330.2012 Concrete and reinforced concrete structures. General provisions. Moscow, 2012 (in Russian).

[2] S. N. Karpenko, Cjepizubov I.G., Shifrin K.S. Concerning test results of sleeve coupling strength for threaded reinforcement bars based on diagram technique // Civil and Industrial Engineering, No. 11, 2008, pp. 44-46 (in Russian).